SUSTAINABLE INDUSTRY:
METAL CASTING INDUSTRY PROFILE

A Preliminary Review of
Metal Foundry and Die-Casting Industry Traits & Trends

Prepared for:

Industry Sector Policy Division
Office of Policy
U.S. Environmental Protection Agency

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PURPOSE OF THIS REPORT

EPA's Sustainable Industry program is based on the premise that by studying and cooperating closely with an industry, government will gain better understanding of the sometimes not-so-apparent factors that influence whether businesses embrace or resist actions to protect the environment. Knowing how and why decisions are made in selected industry sectors, EPA can shape policies that take advantage of incentives for exceptional performance and overcome obstacles to success, leading to long-term continuous improvement by businesses acting in their own self-interest.

EPA is launching a Sustainable Industry project with the Metal Casting industry, including foundries and die-casters. This report compiles basic information—such as structure, financial condition, central trends, environmental and market pressures—that project participants can use as a *starting point* for further research into the traits, trends, and "drivers & barriers" that influence corporate decisions about environmental protection.

An earlier draft of this report was reviewed by members of the American Foundrymen's Society and the North American Die-Casting Association. Their suggestions have been incorporated.

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I. EXECUTIVE SUMMARY

The metal casting industry uses molten metal to form cast metal products and components used in a wide variety of manufactured products. The largest uses of cast metal products include motor vehicles, ingot molds that are re-melted later, pipes, industrial machines, farm equipment, railroad equipment, electric power equipment, and construction materials. Important distinctions within the industry revolve around the type of metal used (ferrous or nonferrous), the volume of castings produced (high volume production in the nonferrous sector is often done using a die-casting process), and the degree of precision required in the cast piece (different casting methods offer varying levels of detail).

The basic casting process involves these five main steps:

- Constructing a replica of the desired cast part (pattern making) out of metal, plaster, plastic, wax, or wood, depending on the specific process being used.

- Preparing a mold into which molten metal can be poured to create the cast part.

- Preparing the proper mix of virgin and/or scrap metal, melting it in a furnace, and pouring the metal into the mold. Castings are then cooled on the shop floor, in a cooling tunnel, or in water to achieve the desired level of solidification before removal from the mold.

- Removing gates and runners which guide the flow of metal during the molding process, removing the casting from the mold, and recovering the mold materials for reuse.

- Finishing, cleaning, and coating the casting to remove excess metal, and to polish and protect finished surfaces.

The domestic metal casting industry includes roughly 2,800 facilities, employing 223,000 people in 1995. Total industry shipments that year were $24.2 billion, or an average of $8.6 million per facility. The nonferrous sector, including both foundries and die casters, comprised 58 percent of all facilities, but less than 40 percent of the value of shipments. Within the ferrous sector, gray and ductile iron foundries are the dominant type of enterprise, comprising more than 60 percent of the total.

Strong economic conditions in recent years have helped the domestic metal casting industry substantially. During 1997, the metal casting industry increased supply capacity for the first time since 1981. Between 1992 and 1996, profits before taxes for ferrous foundries rose from 0.5 percent to 5 percent of sales. Nonferrous foundries also saw an improvement (albeit not as large) in profit margins from 1.9 percent in 1992 to 4.5 percent in 1996. Larger firms, particularly those in the ferrous sector, achieve higher profitability than smaller operations due to economies of scale.

The industry has progressed on many environmental issues, including its emphasis on materials reuse and recycling, and research partnerships with the Department of Energy. Nevertheless, the casting industry faces a number of environmental challenges. These include: source reducing the amount of waste disposed or treated off site, reducing air emissions, and improving its overall energy efficiency.

A number of long-term trends have been reshaping the industry:

Aluminum Replacing Steel. Steel castings have lost market share to aluminum in the transport sector due to increased demand for lightweight, fuel-efficient vehicles.

Import Penetration in Lower Grade Castings. The lower-grade castings market has been largely lost to overseas casters with lower production costs. Domestic producers have successfully retained higher precision castings, in part due to quality and in part due to their ability to deliver “just-in-time” to domestic markets, thereby reducing inventory holding costs.

Increased Outsourcing. Historically, many large manufacturers produced their own castings in-house. Many now rely on external suppliers—both foreign and domestic—that provide certain castings at lower cost.

Consolidation. Although the largest share of casters remain small businesses, increased consolidation has occurred in some sectors of the industry.

Differential Access to Technology Based on Firm Size. Due (at least in part) to consolidation, the industry is taking on a bi-modal structure with the larger operations investing in capital equipment and computer-aided design to produce high precision castings more efficiently, and the small shops continuing to produce in much the same way as they have done for decades.

Opportunities for the Sustainable Industry Project

Industry trends and environmental concerns create both opportunities and challenges from the perspective of an EPA-industry partnership. The following industry characteristics make the metal casting sector attractive for participation in the Sustainable Industry Project process:

Compliance Challenges for Small Businesses. The majority of facilities are quite small, including between 30 and 40 percent that have fewer than 20 employees. Since environmental compliance requires a large upfront investment to understand and respond to the many detailed regulations, small firms are generally more challenged by this complexity. Devoting resources to environmental management is often difficult for small casters since these operations are typically less profitable than larger facilities.

Relatively High Spending on Pollution Controls. While spending on pollution abatement and control as a percent of total costs appear low in an absolute sense (0.7 to 2.7 percent), they are fairly high in a relative sense. Ferrous foundries spent nearly three times as much on environmental controls (as a percentage of total costs) as the overall average for manufacturing. The level for nonferrous foundries was slightly below the overall manufacturing average.

Increased Emphasis on Quality. The industry has placed an emphasis on quality management due to increased international competition and the demands of its customers. For example, the big three U.S. automobile manufacturers have required their Tier 1, 2, and 3 suppliers to become certified in quality management standards. The trend towards quality management provides opportunities for improved environmental performance as well, since many of the skills that make high quality production possible (e.g., statistical process controls) apply to environmental management.

Capital Replacement as Portions of Industry Shift to Aluminum. Another major competitive force in the industry, the broadscale shift from steel castings to aluminum, has led to capital replacement and the potential for improved environmental controls and energy efficiency in the newer equipment. As the industry shifts through changes in products, consolidation, outsourcing, and import substitution, many older facilities are likely to become uneconomic. These firms may require environmental compliance assistance and/or guidance on transitioning out of the market in an environmentally responsible manner.

Foundry Furnaces Remain Inefficient. Energy expenditures are substantially higher than all spending on pollution controls. In large part, this is due to old, inefficient arc and cupola furnaces used to melt the casting metal. Upgrading old furnaces, or replacing them with more energy efficient, less polluting induction furnaces could bring large reductions in energy consumption.

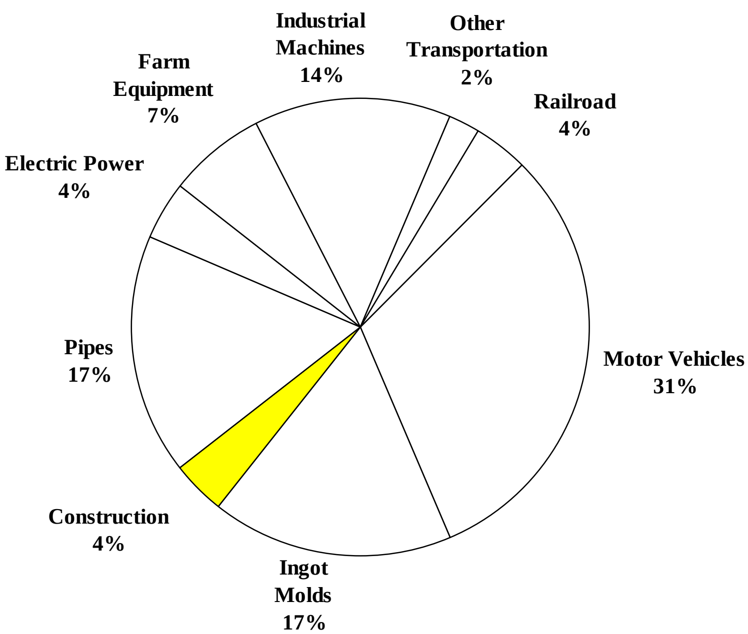
Strong Industry Trade Association Interest. A number of industry trade associations (described in the market overview section) have expressed interest in working with EPA as part of a Sustainable Industry Project. Trade association participation is essential to identifying and implementing promising sector-based environmental protection strategies.

Working with trade associations and other stakeholders, EPA has many opportunities to encourage new investments that include incremental improvements in energy efficiency and environmental controls; to help small business managers improve their environmental performance; and to streamline regulatory requirements so they achieve the same or better environmental results in a manner that is less burdensome for small businesses.

II. INDUSTRY OVERVIEW

Metal castings are produced from molten metal (either ore-generated or recycled) that is poured and cooled in molds constructed of sand, metal, foam, and other materials. The metal casting industry produces both end-use products and components used in a wide variety of products. The American Foundrymen's Society (AFS) estimates that nearly 90 percent of all manufactured products contain one or more cast metal components. Automobiles and other transportation equipment are the largest users of cast metal products (see Exhibit 1), using metal castings for such key parts as engine blocks, crankshafts, brake drums, ship propellers, hydraulic valves, and railroad car wheels. Examples of other common cast metal products include plumbing fixtures, power tools, aircraft parts, jewelry, tableware, sporting goods, and household appliances.

Exhibit 1
Uses of Cast Metal Products



Source: EPA Office of Compliance Sector Notebook Project: Profile of the Metal Casting Industry, February 1998.

Major Industry Segments

Metal casting includes both foundries and die casting facilities. Foundries typically utilize disposable molds constructed of sand and other materials, while die-casters produce castings under high pressure in permanent metal molds. Foundries are usually classified as either ferrous or nonferrous, depending on the type of metals used. Ferrous foundries produce parts cast from gray iron, ductile iron, malleable iron, and steel. Nonferrous foundries use aluminum, beryllium, copper, zinc, lead, tin, nickel, magnesium, and titanium. Die-casting facilities are used to produce large volume, high precision pieces, but can utilize only nonferrous materials. Exhibit 2 provides an overview of ferrous and nonferrous foundry and die-casting classifications, and examples of products.

As shown in Exhibit 2, the metal casting industry is divided into two major Standard Industrial Classification (SIC) codes (332 and 336), representing the ferrous and nonferrous sectors. In addition, the industry also has a relatively

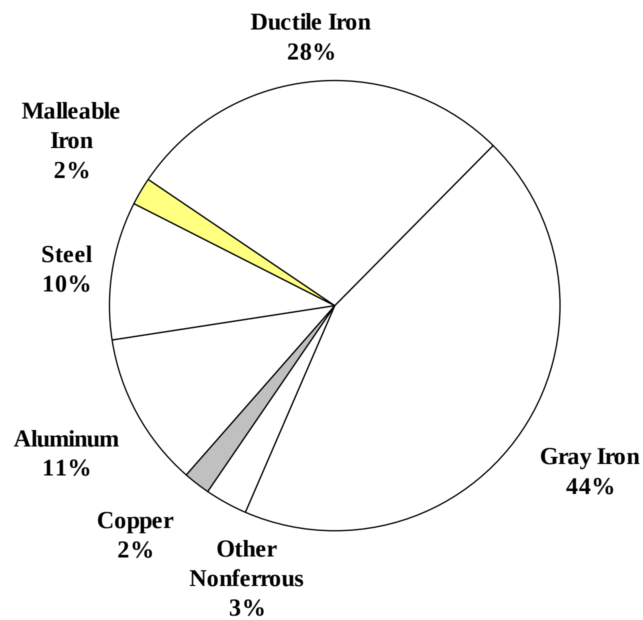
Exhibit 2
Metal Casting Facility Classification

	SIC Description	SIC	Examples of Products
Ferrous Foundries	Gray and Ductile Iron	3321	Engine Components, Pumps, Electricity Transmission Parts
	Malleable Iron	3322	Electricity Transmission Parts, Conveyor and Landing Equipment, Railroad Hardware
	Steel Investment	3324	Machine Tools and Dies, Golf Club Heads
	Steel Foundries N.E.C. (e.g., carbon steel, steel alloys)	3325	
Nonferrous Foundries	Aluminum	3365	Engine Blocks, Cylinder Heads
	Copper	3366	Plumbing Fixtures, Power Transmission Parts, Industrial Valves
	Nonferrous Foundries, except Aluminum and Copper (e.g., Zinc, Lead, Tin, Nickel, Magnesium, Titanium	3369	Valve Covers, Transmission Cases, Power Tools, Sporting Goods
Nonferrous Metal Die Casters	Aluminum	3363	Aluminum Transmission Cases, Valves, Aircraft Parts
	Nonferrous Die Casters, except Aluminum (e.g., Zinc, Lead, Tin, Nickel, Magnesium, Titanium, Copper, Beryllium	3364	Jewelry, Tableware, Household Appliance Parts

small number of operations that are part of a larger facility classified by an SIC code other than 332 or 336. Such facilities are known as "captive" foundries or die casting facilities and are most often found at the plants of automobile and other transportation equipment manufacturers, including General Motors, Ford, Chrysler, John Deere and Caterpillar. While the exact number of captive facilities varies among the metal casting sectors, these in-house operations generally account for a low percentage of market share in comparison with that of independent foundries and die casting firms, and have been declining as larger firms have increased their outsourcing of casting services.

The metal casting industry produced 13 million tons of castings in 1996. As illustrated in Exhibit 3, despite inroads of aluminum in the automotive market, gray and ductile iron continue to account for nearly 75 percent of all ferrous and nonferrous castings.

Exhibit 3
Types of Metals Cast



Source: EPA Office of Compliance Sector Notebook Project: Profile of the Metal Casting Industry, February 1998.

III. METAL CASTING PROCESSES

General Process Overview

Metal casting involves five process steps: (1) pattern making; (2) mold and core preparation and pouring; (3) furnace charge preparation, metal melting, and pouring; (4) shakeout, cooling, quenching and sand handling; and (5) finishing, cleaning, and coating.[1]

Pattern making involves constructing a replica or "pattern" of the desired cast part, shaped from metal, plaster, plastic, polystyrene, wax, or wood, to use in constructing a mold. Patterns are usually constructed by specialty shops using sophisticated design and production techniques.

Major casting processes (summarized in Attachment A) are defined by the means and materials they use for **mold and core preparation and pouring**. The mold is the cavity into which molten metal is poured. Depending on the shape of the part being cast, cores may be placed inside the mold to create internal openings within the casting. The type of casting process used determines the detailing achievable, the number of casts that can be produced, and the amount and type of waste from the casting process.

In **furnace charge preparation, metal melting and pouring**, scrap metal and/or metal ingot is melted in a furnace and poured in molten form into the mold. The process includes cleaning and/or degreasing the metal with solvents and other cleaners and burning off any organics. Flux, a material usually consisting of chloride or fluoride salts, is often added to the molten metal to remove impurities.

The **cooling, quenching, shakeout, and sand handling** stage follows metal pouring. During this stage, foundry molds are cooled on the shop floor or in a cooling tunnel before transport to the shakeout area. Some foundries and die casters cool castings rapidly to impart desired metallurgical properties by quenching them in plain or chemically-altered water. Foundries using sand molds utilize vibrating grids and/or conveyors to shake the sand mold from the casting. The sand is then processed to remove lumps, metal, binders, impurities, and fine particles. Most of the sand is reused onsite, with any remaining waste sand being sent offsite for disposal or use as a construction material. Other foundry processes may require separating the cast from the mold manually.

The final casting process step involves **finishing, cleaning, and coating**. Once cooled, all castings require some degree of cleaning and finishing in which excess metal is removed using abrasive cutting wheels, band saws, hammers, and other devices. Some finishing processes sand blast or steel-shot blast to remove oxides and residual material. Cleaning involves using organic solvents, emulsifiers, pressurized water, abrasives, alkaline agents, or

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[1] More detail on metal casting processes is also provided in the *Metal Casting Industry Sector Notebook* prepared for the U.S. EPA Office of Compliance in February 1998. This notebook is the principal source used for this summary.

acid to remove dirt, grease, oil, oxides, and rust. Once clean, many castings require the application—either on site or by specialty shops—of protective coatings, often resins or other metals.[2]

IV. INDUSTRY CHARACTERIZATION

In this section, we provide a brief overview of important attributes of the metal casting industry. Unless otherwise noted, the analysis does not include the few captive casting facilities.[3] A **Market Overview** offers background data on the number and size of producers, the overall market size, the largest market segments, market concentration, and trade association representation. A **Financial Overview** examines the industry's cost structure, including its Pollution Abatement and Control Expenditures (PACE); its profitability; and its ability to access capital for plant expansions, improvements, or purchases.

Market Overview

According to the most recent statistics gathered by the Department of Census, approximately 2,800 metal casting establishments operate in the United States. Forty-two percent, or 1,178 facilities, are iron and steel foundries (SIC 332), representing 61 percent ($14.7 billion) of total 1995 industry shipments of $24.2 billion. The remaining 58 percent (1,634) of metal casting establishments are nonferrous foundries and die casters (SIC 336), with total 1995 shipments of $9.5 billion.

Largest Segments. More than a quarter of all establishments are gray and ductile iron foundries (713 establishments). Nearly a third of all establishments are aluminum foundries (591 establishments) or aluminum die casters (333 establishments). Sixteen percent work with steel, twelve percent with copper, and the remaining four percent with other metals.

Employment. Total 1995 employment for all metal casting sectors was 223,000. The average labor intensity of operations varied quite widely across sectors, with much higher levels in the ferrous foundries (with over 100 employees per facility) than in nonferrous foundries (roughly 50 employees per facility). Aluminum die casting facilities, although somewhat lower than ferrous foundries, averaged 98 employees per establishment.

Firm Size and Market Share. As shown in Exhibit 4, most market segments are populated primarily by small firms, often with fewer than 20 employees. In each segment, however, a smaller number of large firms captures most of the market share. For example, as shown in Exhibits 5 and 6, significantly more than half of all value of shipments (VOS) was generated by establishments

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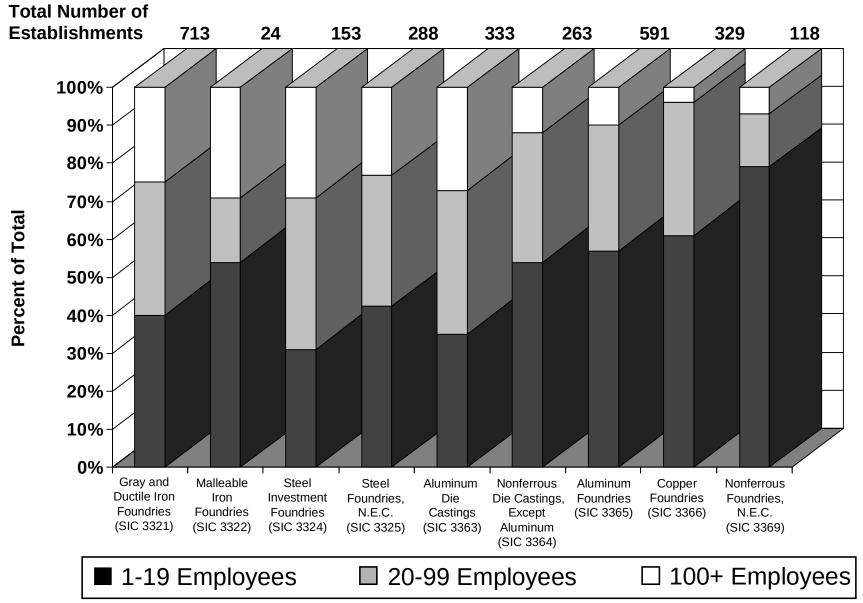
[2] Protective coatings include electroless nickel plating; other metal coatings applied through electroplating, hard facing, hot dipping, thermal spraying, diffusion, or conversion; and organic or fused dry-resin coatings.

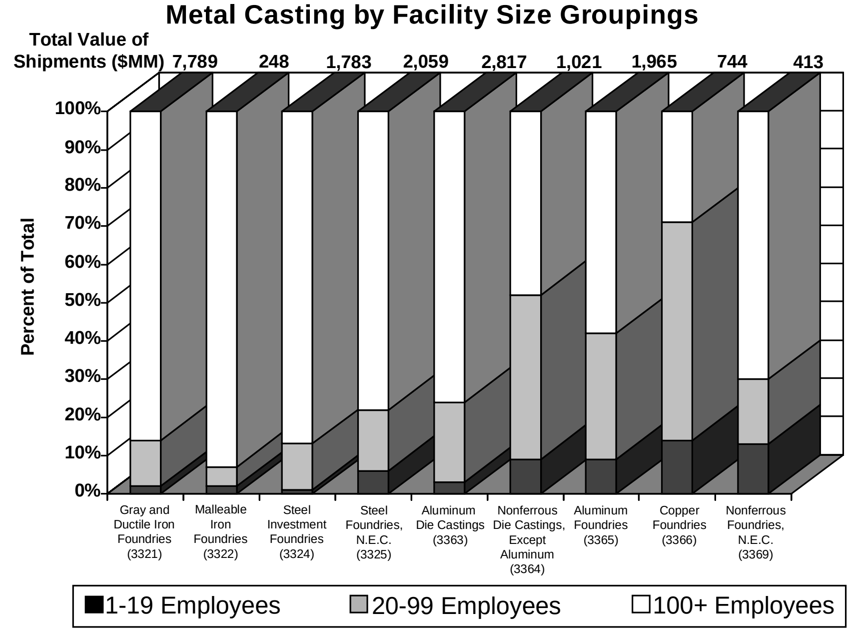
[3] Captive casting facilities are those operating within larger corporate entities that are classified under a SIC code other than 332 or 336. Since most industry data are organized by primary SIC code, captive facilities are not included in this analysis.

Exhibit 4
1992 Percent Distribution of Metal Casting Establishments by Facility Size Groupings



Source: Bureau of the Census. *1992 Census of Manufacturers: Ferrous and Nonferrous Foundries* (Washington, D.C.: Bureau of the Census, 1995.) Table 4.

Exhibit 5
1992 Percent Distribution of Value of Shipments for Metal Casting by Facility Size Groupings



Source: Bureau of the Census. *1992 Census of Manufacturers: Ferrous and Nonferrous Foundries* (Washington, D.C.: Bureau of the Census, 1995.) Table 4.

with 100 or more employees. Similarly, 93 percent of malleable iron VOS and 86 percent of steel investment foundry VOS came from the largest establishments.

Geographic Concentration. Casters are often located close to the major markets for their parts. Thus, as shown in Exhibit 7, a significant cluster of metal casters can be found in the industrial/automobile manufacturing belt of the central United States (Ohio, Michigan, Illinois, Wisconsin, and Indiana). Pennsylvania (due to the historically large production of steel) and California (perhaps due to computer parts) also have substantial numbers of casting facilities. Forty-four percent of all metal casters are located in these seven states.[4]

Trade Association Representation. The major trade associations for the metal casting industry are: the American Foundrymen's Society (AFS), the North American Die Casting Association (NADCA), the Non-Ferrous Founders' Society (NFFS), the Steel Founders' Society of America (SFSA), the Investment Casting Institute (ICI), the Casting Industry Suppliers Association (CISA), and The Ferroalloys Association (TFA). The American Foundrymen's Society (AFS) is the largest of the trade associations with a membership of approximately 12,800; the North American Die Casting Association (NADCA) is the second largest with a membership base of 3,200. With the exceptions of ICI (Dallas) and TFA (Washington, DC), all of the trade groups are headquartered in Illinois.

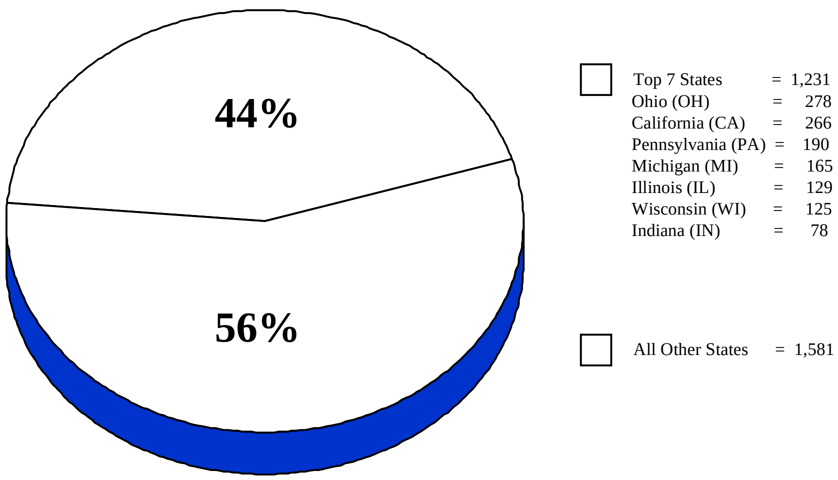
[4] In addition to these states, industry representatives note that Alabama is emerging as a major metal casting center.

Exhibit 6 1992 % Concentration of Value of Shipments (VOS) By Top 4, 8, 20, and 50 Companies					
SIC Description	**SIC Code**	**VOS for Largest 4 Companies (%)**	**VOS for Largest 8 Companies (%)**	**VOS for Largest 20 Companies (%)**	**VOS for Largest 50 Companies (%)**
Gray and Ductile Iron Foundries	3321	24	37	56	74
Malleable Iron Foundries	3322	80	95	100	100
Steel Investment Foundries	3324	50	64	79	93
Steel Foundries, N.E.C.	3325	21	32	53	78
Aluminum Die Castings	3363	21	32	53	73
Nonferrous Die Castings, Except Aluminum	3364	16	27	49	75
Aluminum Foundries	3365	16	24	41	62
Copper Foundries	3366	13	23	40	64
Nonferrous Foundries, N.E.C.	3369	70	79	89	97
Source: U.S. Bureau of the Census. 1992 Economic Census: Report Series (Disc 1). (Washington, D.C.: U.S. Bureau of the Census, 1996).					

Financial Overview

Examining the industry's cost structure, profitability, and capital markets highlights opportunities for improved financial and environmental performance. For example, focusing on the industry's cost structure reveals the percentage of total expenditures on labor, capital, pollution control, and energy. Highlighting these large cost elements can focus management attention on activities that reduce costs and lead to environmental improvements. Industry profitability and access to capital are also key considerations as these factors affect opportunities for plant reinvestment, operational improvements, and improved environmental performance.

Exhibit 7
Geographic Concentrations of Foundries and Die Casters, 1992
(Top 7 States for 1992 Number of Establishments in SIC Major Groups 332 and 336)



Total Establishments in the U.S. = 2,812

Source: Bureau of the Census. *1992 Census of Manufacturers: Ferrous and Nonferrous Foundries* (Washington, D.C.: Bureau of the Census, 1995.)

Cost Structure

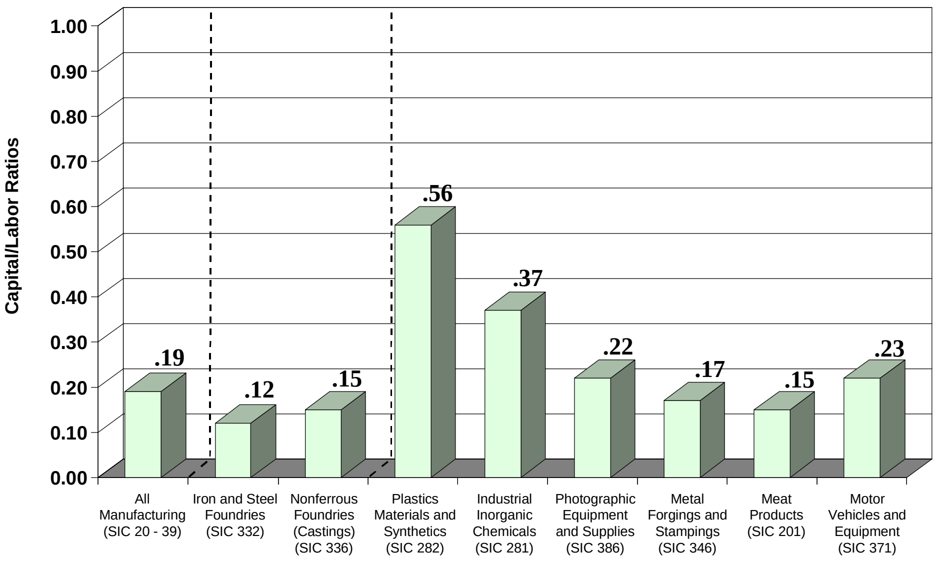
The overall cost structure is fairly uniform throughout the metal casting industry. By far the largest proportion of expenditures is spent on labor and materials; all metal casting sectors spend at least 90 percent of expenditures on these two components. With a range of one to eight percent of total expenditures spent on capital, metal casting sectors are not far from the overall manufacturing average of five percent spent on capital.

Materials Comprise Largest Cost in Most Industry Segments. For the majority of metal casting sectors, materials form the largest percentage of expenditures. With a range of 41 to 61 percent of total expenditures, the material cost percentage of the metal casting industry falls short of the overall manufacturing industry average of 70 percent. Material reuse and recycling may account for the industry's relatively low materials costs.

Spending on Energy Greatly Exceeds Manufacturing Average. Energy (both purchased fuels and electricity) is an extremely important component of material costs. Comprising 4 to 6 percent of total expenditures in SIC 336 and 332 respectively, energy costs in this sector are two to three times the average for the manufacturing industries overall.

Metal Casting Remains a Labor Intensive Activity. The metal casting industry is labor intensive, with all sectors spending nearly 40 percent or more on labor costs. This cost percentage is much higher than the average of 25 percent spent on labor by manufacturing industries overall. Exhibit 8 shows that the capital to labor ratio within metal casting is lower than for all manufacturing. This could be attributable to the large number of older, more labor-intensive metal casting firms. Furthermore, the labor intensity of production appears linked to the overall health of the sector. For example, in the Malleable Iron Foundries subsector (SIC 3322), labor costs actually exceeded material costs. This sector is reported to be in a period

Exhibit 8
1995 Capital/Labor Expenditure Ratios by Industry Group
(Metal Casting and Other Selected Industries)

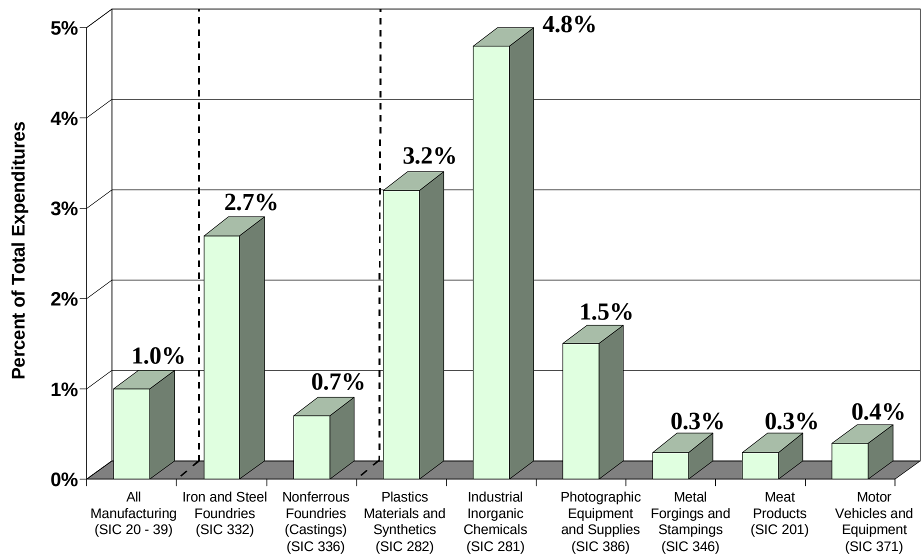


Source: Bureau of the Census. *1995 Annual Survey of Manufacturers: Statistics for Industry Groups and Industries* (Washington, D.C.: Bureau of the Census, 1997.) Tables 2 and 3.

of severe decline characterized by lower capacity utilization of older, more labor-intensive facilities that do not appear to have been upgraded.

Spending on Pollution Abatement and Control Sometimes Exceeds Manufacturing Average. Exhibit 9 shows total pollution abatement costs relative to total expenditures for nonferrous and ferrous casting sectors of between 0.7 and 2.7 percent of total expenditures, respectively. Most of the spending is on operating measures rather than pollution prevention and control capital, reflecting the relatively low capital utilization in the sector. In the ferrous sector, the bulk of pollution control expenditures (52 percent in 1994) are on air pollution control (followed by solid waste and water pollution expenditures), although the percentage spent on air pollution control has decreased over time. In the nonferrous sector, pollution abatement expenditures are more evenly distributed over media, with the highest percentage spent on water pollution control, followed by solid waste, and air pollution. Although the spending appears low in absolute terms, the spending within the ferrous sector is nearly three times the average for the manufacturing sector overall.

Exhibit 9
1994 Ratio of Total Pollution Abatement to Total Expenditures by Industry Group
(Metal Casting and Other Selected Industries)



Source: Bureau of the Census. *1995 Annual Survey of Manufacturers: Statistics for Industry Groups and Industries* (Washington, D.C.: Bureau of the Census, 1997.) Tables 2 and 3.
Bureau of the Census. Current Industrial Report, Pollution Abatement Costs and Expenditures: 1994 (Washington, D.C.: Bureau of the Census, 1996.) Tables 3 and 7.
Note: 1994 was the last year for which this report was issued.

Profitability

Trends in sector profitability highlight two important points. First, the recent economic expansion has been good for the industry, allowing profit margins to increase markedly. Second, margins at larger firms are substantially higher than smaller ones, suggesting that broad industry averages may mask substantial problems within segments of the industry.

Rising Profit Margins. Between 1992 and 1996, profits before taxes as a percentage of sales for ferrous foundries have risen from 0.5 percent to 5 percent. During the same time period, nonferrous foundries experienced an overall increase in profitability from 1.9 to 4.5 percent.

Larger Firms Performing Substantially Better in the Ferrous Sector. Among ferrous foundries, there is a significant discrepancy between profit margins for larger and smaller firms. In 1996, ferrous foundries with shipments of more than $25 million had profit margins of 7.6 percent, while smaller firms (with sales of less than $10 million) had margins of only 4.2 percent.

Larger Firms Performing Marginally Better in the Nonferrous Sector. For nonferrous foundries, volume of sales apparently has less of an impact on profitability; with smaller firms ($1 - 10 million in sales) reporting profit margins of 4.1 percent, and larger operations ($25 million or more in sales) reporting 5.2 percent.

Overall Profitability Compares Reasonably Well to Other Industries. Profit margins in 1997 for ferrous and nonferrous foundries are equivalent or better than similar industries such as iron and steel forgings (3.9 percent), metal stampings (4.5 percent), and motor vehicle and passenger car bodies (3.7 percent). However, for foundries of all sizes that produce lower quality commodity pieces, profit margins are constrained by low-cost overseas competition.

Access to Capital

Data on access to capital within the casting sector are difficult to obtain. Although four ferrous foundries are publicly traded (Atchison Casting, Citation, Intermet, and Wescast, with a combined market value in 1997 of $1.2 billion), most foundries are privately owned by families or private partnerships. Without access to capital markets, the majority of metal casters rely on traditional sources of capital for small businesses—profits and bank loans—to make significant investments in operations. While improving profitability makes capital from these sources easier to obtain, we were unable to ascertain the overall adequacy of available capital within the industry.

A 1997 *Foundry Management and Technology* article on capital markets and the foundry industry emphasizes the growing presence of institutional private equity firms (also called "buyout" firms). Buyout firms raise money from corporate and public pension funds and leverage this money with debt (bank loans or bonds) to buy individual companies or assemble conglomerates that they believe occupy unique and lucrative market niches. Buyout firms can facilitate a transition from a family-owned business to a public offering (where appropriate), or they can engineer an industry consolidation.[5] For medium and larger metal casters with strong market niches and updated operations, there appear to be abundant sources of capital, including buyout firms. It is not clear that the same sources of capital are readily available to smaller, less-modernized metal casters.

[5] Lionheart Industries, which includes Quaker City Castings and Penatek Industries, is an example of a strategic consolidation within the casting industry using the buyout approach.

V. INDUSTRY TRENDS AND PROJECTIONS

The metal casting industry has been reshaped by a number of important trends over the past twenty years. Increased pressures for energy-efficient transportation have driven a long-term shift from steel to aluminum castings in the transportation segment of the market. Increasing pressure from imports has driven most of the lower-quality castings abroad, where labor and regulatory costs are lower. In the high-quality castings segment, quality programs to reduce manufacturing defects have helped keep costs in line. Cost pressures have also led to increased use of technical innovations such as computer-aided design and automation. Large corporations have shut many of their in-house captive casting operations to take advantage of both of these trends: less expensive castings from abroad, and increasingly high quality castings available domestically. Finally, the industry has experienced additional consolidation as firms broaden their casting services to meet the requirements of the increasingly global marketplace.

The current market situation is characterized by very intense competition, especially in the highest volume sectors such as automobile production, but increasingly in other sectors as well. Recent acquisition activities have brought new technology, increased investment capital, and “rock-bottom pricing” to the lower volume sectors, which have historically had higher margins and less intense competition.

While these pressures have forced difficult changes in the castings industry, the health of the sector overall is actually fairly good. In 1997, the metal casting industry increased supply capacity for the first time since 1981. Shipments of all U.S. metal castings were expected to continue to grow in 1998. Forecasters predict that strong U.S., Asian, and European markets will fuel a seven percent increase in total U.S. shipments; it is unclear how turmoil in Asian markets has affected this trend. Growth in castings shipments will be spurred by increased production of automobiles, farm and construction equipment, as well as other durable goods.

The forecasted growth in U.S. castings shipments will not affect each segment of the industry equally, however. The growth is expected to be led by ductile iron and aluminum, and tempered by declines in malleable iron, and zinc die castings. Growth is also focused on the larger, more technically advanced facilities. In 1997, the largest foundries (250 employees or more) experienced the most growth in castings shipments, while the smallest foundries (fewer than 20 employees) experienced the slowest growth.

The remainder of this section provides additional details on the major forces that have reshaped the industry, as well as the industry’s response to them.

Decline of the Ferrous Sector and the Rise of Aluminum

Demand for ferrous metal castings grew steadily between 1950 and 1970, hitting a record high of more than 20 million tons in 1973. A combination of factors, however, began to reverse this growth. Average annual shipments dropped from 17.5 million tons in the 1970s to only 11 million in the 1980s. While shipments have recovered somewhat from a low of 8.7 million tons in 1985, 1996 shipments remained less than 12 million tons, despite the extremely strong domestic economy. Declining shipments hurt the industry badly: of the 2,300 ferrous foundries operating in the 1960s, only 1,800 remained in the early 1980s, and only 1,100 in the early 1990s.

Nearly every ferrous segment experienced adverse competitive pressures; these trends are illustrated in Exhibit 10, and described below:

- *Gray iron*, widely used in automobile construction, was hard hit by the federal corporate average fuel economy (CAFE) standards that became effective in the mid-1980s. Reducing automotive weight was one of the most cost-effective ways to meet CAFE standards, often accomplished by replacing gray iron castings with aluminum. Additionally, new continuous casting technologies largely replaced steel rolling and made ingot molds, another traditionally large market for gray iron castings, almost obsolete. Demand for gray iron plummeted from 15 million tons annually in 1965 to only 6.2 million tons today.

Exhibit 10

Market Trends in Metal Casting, By Sector

Description	Year of Peak Shipments	Key Substitutes*	Key Segment Trends
Ferrous Castings	1973 20 million tons		Number of facilities has dropped by half since the 1960s.
Gray iron	1965 15 million tons	Aluminum, Ductile Iron	In decline since mid-1980s when replaced with aluminum in autos and when demand for ingot molds dropped.
Ductile iron		Aluminum	Austempered ductile iron now competing with steel; offsetting the decline in gray iron.
Malleable iron	1969 1.2 million tons	Aluminum, Ductile Iron	Shipments declining due to cheaper substitutes.
Steel		Aluminum, Ductile Iron	Demand sensitive to freight car production; under increasing pressure from ductile iron.
Nonferrous Castings	1994 2.5 million tons		Shipments have been growing since the 1950s.
Aluminum (die-casting and foundries)	1978 1.6 million tons	Plastics, Composites	Significant growth in aluminum demand from the automotive industry.
Copper	1943 760,000 tons	Stainless Steel, Teflon Coated Ductile Iron, Plastics	Annual shipments peaked in 1943; vulnerable to substitution by other materials.

* The entire metal casting industry faces competition from plastics, ceramics, composites, and lighter alloys.

- *Malleable iron* is the toughest of all cast irons. The most significant markets for malleable iron include connecting rods for cars and light trucks, and plumbing valves and fittings. However, the development of cheaper substitutes for less demanding market niches has led to its decline from 1.2 million tons in 1969 to only 262,000 tons in 1996 (down 11 percent from 1995).[6]

- *Steel castings* have been used primarily in the freight car industry, and suffered in the 1980s as freight car construction declined precipitously from 90,000 in 1973 to only 6,000 four years later. The 1980s were a particularly hard decade for steel castings. In the 1960s and 1970s, the industry shipped between 1.5 and more than two million tons annually. By 1983, industry shipments hit a low of 764,000 tons. Although the sector rebounded somewhat in 1996, shipping 1.2 million tons of steel, ductile iron (with shipments of 4.6 million tons in 1996) is expected to become an increasingly strong competitor.

Aluminum, on the other hand, has experienced continuous growth since the 1950s. Shipments of aluminum castings have quadrupled in the past four decades, with an average of 1.4 million tons per year for the first seven years of the 1990s. Aluminum castings also dominate the nonferrous sector in general, comprising 78 of total nonferrous shipments. Other nonferrous sectors, including copper, zinc, and magnesium, are quite small. Both copper and zinc have lost market share due to competition from a wide range of less expensive substitutes. Magnesium has low current shipments, but strong engineering properties that make it a potentially attractive metal for long-term growth in high performance market niches. In the near-term, however, the aluminum sector will continue to drive the nonferrous market.

Since one pound of aluminum can offset the weight of 2.25 to 2.5 pounds of cast iron in a new automobile, the 1.4 million tons of aluminum castings translate to over 3 million tons per year in reduced demand for gray iron. Manufacturers generally have felt that the benefits of reduced automobile weight has been sufficient to offset the 30 to 100 percent price premium over steel.[7] Die cast aluminum comprises roughly 60 percent of the cast aluminum market, and is expected to grow by about 1.6 percent per year. Foundry casting is expected to grow at an even faster rate (four percent per year) due to increased usage of aluminum engine blocks and cylinder heads in automobiles.

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[6] Many manufacturers are replacing malleable iron with lighter materials such as plastics, ceramics, composites, lighter alloys, and nonferrous castings (e.g., aluminum). Within ferrous metals, castings made of lighter ductile iron are also replacing malleable iron castings. In addition to being lighter, ductile iron has unique compatibility with new casting techniques, known as "near-net shapes," which allow for thinner-walled castings with intricate and complex shapes.

[7] Aluminum is three to five times as expensive as steel on a per pound basis, but requires only one pound of aluminum for each 2.25 pounds of steel replaced. The effective cost of aluminum in automotive applications is therefore roughly 133 to 200 percent the cost of steel.

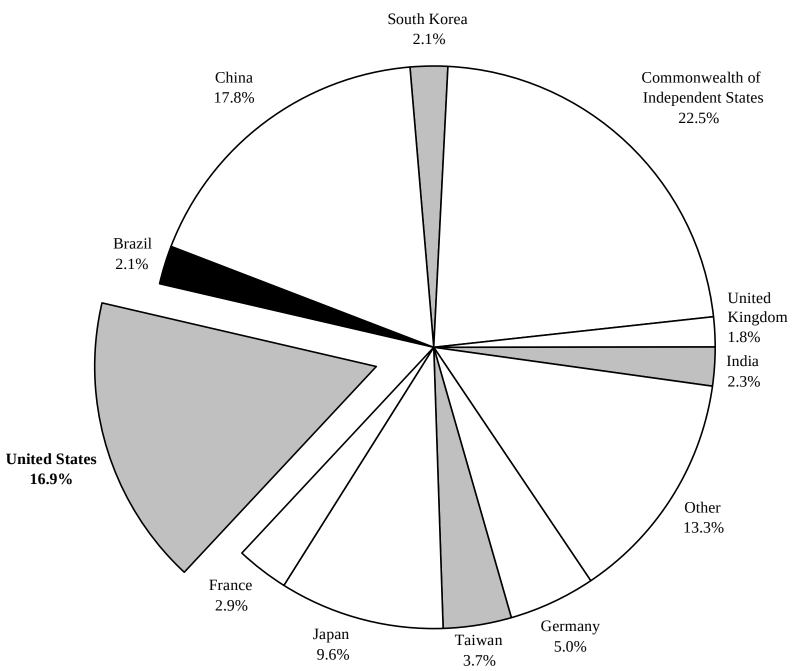
Increased Import Penetration and Domestic Response

The domestic metal casting industry faces stiff competition from foreign imports. Lower labor and material costs, less strict environmental and safety standards, and favorable interest rates for capital investment available in many foreign nations have contributed to an erosion of the U.S. position in many market segments. For the ferrous sector, the largest erosion in market share occurred in the late 1970s; in the nonferrous industry, it occurred in the 1980s. Foreign competition has successfully taken over some U.S. castings markets, including: steel and iron valves (China, Taiwan, India), steel construction parts (South Africa), municipal iron (India), aluminum die castings (Korea), gray iron engine/compressors (Brazil), malleable iron fittings (Thailand), and gray iron power transmissions (India). Global casting is shown in Exhibit 11.

In conjunction with the marketplace pressures on ferrous castings described above, imports helped trigger a wide-ranging response by domestic producers to remain viable. The broad response was to improve quality and efficiency, using the approaches described below.

Implementation of Quality Management Systems. Implementation of total quality programs by many casters contributed not only to improvement in product quality, but to cost reductions as well, through reduced materials wastage and lower parts retrofit costs. These changes have allowed the U.S. producers to shore up their market positions in most segments of the industry, and to become the preferred suppliers to higher-end casting users, where quality and timely delivery are especially important. As a result, the trade balance in nonferrous castings has improved since the early 1990s; and that of ferrous castings improved since the late 1980s. Many metal casting facilities have developed quality management systems that meet the requirements of internationally recognized standards. By the end of 1997, 17 percent of metal foundries had achieved some level of ISO (International Organization for Standardization) or QS (a management system for suppliers of the automotive industry) accreditation, a six percent improvement over 1996. Companies in the ductile iron and steel foundry industries have achieved 31 percent and 25 percent accreditation, respectively.

Exhibit 11
World Metal Casting Production



Source: American Foundrymen's Society, *Modern Casting*, 1994.

Technical Innovation and Increased Productivity. Technical innovation has dramatically improved the metal casting industry, and allowed it to compete with foreign producers using less expensive labor and raw materials. Within the production process, technological innovations such as computer-aided design and automation have streamlined production, reduced waste, improved casting finish and accuracy, and reduced costs. In 1996, a downsized metal foundry sector produced more total tonnage than in any of the previous 15 years. Technical innovation—in both materials and processes—is expected to remain a central driver of restructuring in the casting industry. For example, as automobile manufacturers develop lighter, more fuel efficient vehicles, they require new cast parts made from lighter and stronger materials such as titanium aluminide automotive valves that can support a higher engine temperature and are 50 percent lighter than the current valves.[8] Market analysts expect metal casting will continue its gradual process of automation, with the advancement of sensors, computer modeling, and quality control systems. Over the longer-term, intelligent processing methodologies (IPM), which allow a production system to evolve and "learn" as it confronts different stimuli, are expected to be adopted as well.

Consolidation. As noted in the market overview section, the metal casting industry has been experiencing consolidation. Consolidation of industries such as metal casting, where many of the plants are small, family-owned enterprises, often leads to large increases in efficiency. Multiple-plants can benefit from common managerial and control systems, such as computerized record keeping, billing, and part design. Consolidated entities can also more easily access capital to upgrade facilities, and often offer "one-stop shopping" to customers, allowing them to market their products to a broader customer base. While consolidation can increase the competitive pressure on small, independent businesses that remain, it provides many small business owners with an opportunity to sell their business and helps the domestic industry overall to stem the tide of imports.

Outsourcing. A desire for more cost-effective metal casting services is also partly behind another recent and noteworthy trend within the metal casting industry—the continued move away from captive, or in-house, facilities. As late as the 1960s, it was common for large manufacturers of automobiles, farm equipment, household appliances, and other goods to meet all of their metal casting needs through captive foundries and die casting divisions within their assembly plants. By the mid-1980s, economic recession had forced

[8] Just as technological innovations can create demand for cast metal parts, so too can they diminish it. For example, improvements in plastics are allowing the material to make inroads into markets traditionally served by metal castings, such as pipes. Plastics, as well as ceramics are also beginning to capture automotive applications previously served by cast metal.

Exhibit 12

Percent of Market Share Represented By Independent vs. Captive Metal Casting Facilities

SIC Code	Value of Primary Product Shipments by All Industries (million dollars)	Value of Primary Product Shipments by Industry Classified under SIC 332 or 336 (million dollars)	Value of Primary Product Shipments by Industries Not Classified under SIC 332 or 336 (million dollars)	Coverage Ratio (%)
3321: Gray and Ductile Iron Foundries	7,477	7,291	186	98%
3322: Malleable Iron Foundries	302	232	70	77%
3324: Steel Investment Foundries	1,632	1,606	27	98%
3325: Steel Foundries, N.E.C.	1,971	1,903	69	97%
3363: Aluminum Die Castings	2,547	2,457	91	96%
3364: Nonferrous Die Castings, Except Aluminum	1,087	903	184	83%
3365: Aluminum Foundries	1,873	1,715	158	92%
3366: Copper Foundries	750	662	89	88%
3369: Nonferrous Foundries, N.E.C.	463	379	84	82%

1. Source: Bureau of the Census, *1992 Census of Manufactures: Ferrous and Nonferrous Foundries*, (Washington, D.C.:, Bureau of the Census, 1995). Table 5b.
2. Primary product refers to any metal casting. The coverage ratio represents the proportion of metal casting (primary product) value of shipments from facilities classified under SIC 332 or 336 as opposed to that from facilities classified under other SIC codes.

the consolidation or closure of many of these captive operations. Even with the resurgence of automobile and other kinds of production, manufacturers continue to find outsourcing the most cost-effective means of meeting many of their casting needs. As shown in Exhibit 12 below, captive facilities are extremely minor players in most market segments. Even in malleable iron casting (SIC 3322), where the captive share of total production is about 23 percent, the trend is away from captives, declining from a 50 percent market share twenty years ago.

VI. OVERVIEW OF ENVIRONMENTAL ISSUES

The metal casting industry uses large quantities of energy; emits substantial quantities of volatile organic compounds (VOCs), hazardous air pollutants (HAPs), and other pollutants to the air; and generates large amounts of waste metal and casting sand. This industry has made important strides in recovering and recycling materials; 61 percent of TRI transfers in the ferrous foundry sector go to recycling facilities (though the ultimate percentage recovered is not known). The same statistic for nonferrous die casters is an impressive 97 percent, reflecting the high value of scrap aluminum. The metal casting industry also represents one of the oldest and largest recyclers in North America, utilizing approximately 15-20 million tons of scrap or waste metal a year in the production of castings. It is one of the largest outlet markets for secondary aluminum. In addition, the industry reduced TRI releases (per million dollars of value added) by 30 percent between 1990 and 1995.[9]

Despite these encouraging statistics, the industry remains the source of roughly 3 percent of total emissions reported to TRI, and has an emissions intensity higher than the average for all manufacturing. Although most transfers are sent to recyclers, the waste materials intensity of the sector is four times the average for all manufacturing, suggesting opportunities for increased process efficiencies. Other areas for environmental improvement include reducing air pollution and waste production, increasing energy efficiency, and ensuring environmental compliance and innovation for all metal casting facilities.

Waste Characterization

Due to the fundamental differences in their processes, foundries and die casting facilities generally have distinct wastestream characterizations:

- **Foundries** using sand molds and cores generate spent sand waste that can account for as much as 56 to 90 percent of the total waste streams of the facilities, as cited by U.S. EPA's *Metal Casting Industry Sector Notebook*. Approximately two percent of the spent sand may be hazardous.

- **Foundries** also generate significant quantities of the following wastes: volatile organic compounds (VOCs) and potential hazardous air pollutants (HAPs) from the use of chemical binding systems; wet scrubber wastewater from facilities using certain types of large furnaces; metal contaminated water from the cooling

[9] This reduction is based on normalized TRI emissions data to account for changes in industry composition between the periods. Value added is a common measure of the economic value created by a particular manufacturing process. It is calculated by subtracting the key manufacturing costs (materials, supplies, containers, fuel, purchased electricity, and contract work) from the value of shipments. Using value added as a standard improves the basis for comparing industries' environmental performance by controlling for changes such as industry size and output fluctuations. We were unable to calculate a time trend for transfers due to anomalies in the TRI data set.

process; and, slag, a glassy mass with a complex chemical structure that is a by-product of the melting process which may comprise as much as 25 percent of a facility's solid waste stream.

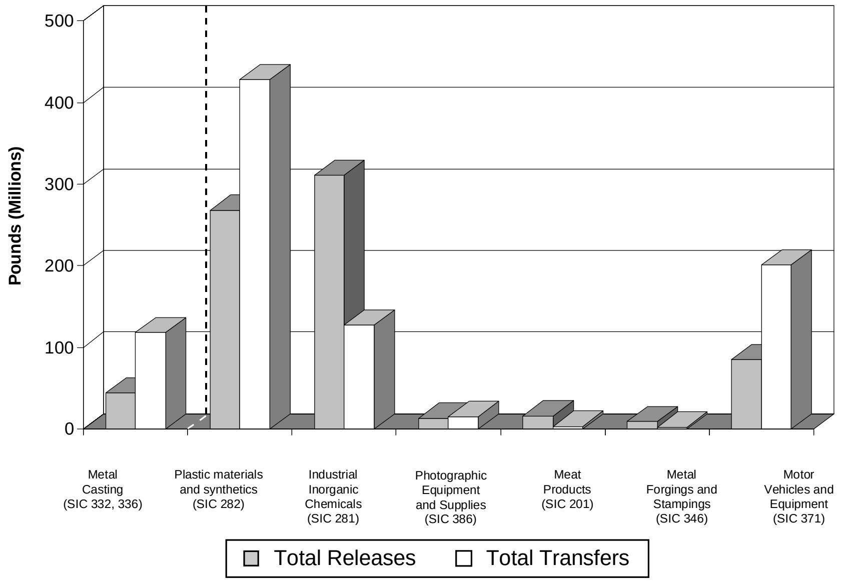
- **Die-casting** waste streams are dominated by various types of air emissions. The die-casting process generates less solid waste than most foundry processes since molds are reused. Common sources of air emissions include the following: die lubrication and plunger tip lubrication, which can result in high levels of VOCs and other pollutants to the air and oil and phenols in wastewater; the fluxing and dross removal process, which can give off hydrochloric acid, oxide fumes, and other pollutants; and, finishing and cleaning operations, resulting in emissions of VOCs and hazardous air pollutants (HAPs).

- Both **foundries and die-casters** are a source of common air pollutants, such as particulates, carbon monoxide, nitrogen oxides, and sulfur compounds.

Reported Toxics Release Inventory Emissions

Metal casting facilities (among other industries) are required to report annual data regarding their waste production of a specific set of HAPs and other toxic chemicals for the Toxics Release Inventory (TRI) database. While an imperfect measure of environmental performance, the TRI data provide a useful overall picture of emissions and emissions intensity within an industry. Limitations of TRI include: not every industry reports; not all emissions are reported; data quality is sometimes uneven; and emissions values are not adjusted to reflect their relative toxicity.

Exhibit 13
Summary of 1995 TRI Releases and Transfers for Metal Casting and Other Selected Industries

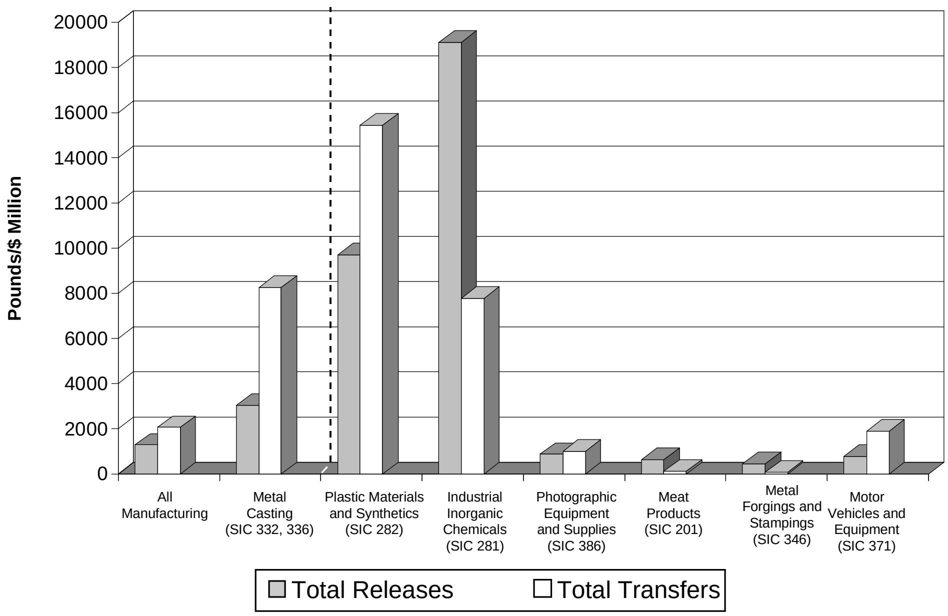


Sources and Notes: *1987-1995 Toxics Release Inventory CD-ROM*, August 1997; *1995 Annual Survey of Manufacturers* (Washington, D.C.: Bureau of the Census, 1997). Total releases and transfers for metal casters differ somewhat from those calculated in EPA's *Profile of the Metal Casting Industry*, presumably due to differences in what data fields were summed to calculate totals. Our conclusions are not affected by this disparity.

Aggregate Emissions

In 1995, the metal casting sector released 43.5 million pounds and transferred an additional 118 million pounds. This accounted for roughly three percent of all TRI releases and transfers by manufacturing facilities required to report TRI emissions. As compared to other industries of interest to EPA, metal casting had lower emissions than some, and higher than others; a precise comparison can be seen in Exhibit 13.

Exhibit 14
Summary of 1995 Normalized TRI Releases for Metal Casting and Other Selected Industries
(Pounds of Releases per $ Million Value Added)



Sources and Notes: *1987-1995 Toxics Release Inventory CD-ROM*, August 1997; *1995 Annual Survey of Manufacturers* (Washington, D.C.: Bureau of the Census, 1997). Total releases and transfers for metal casters differ somewhat from those calculated in EPA's *Profile of the Metal Casting Industry*, presumably due to differences in what data fields were summed to calculate totals. Our conclusions are not affected by this disparity.

A more important question than aggregate emissions involves *emissions intensity*—for a given level of economic output, the amount of pollution emitted. To evaluate emissions intensity, we standardized aggregate emissions data by examining the pounds of TRI releases and transfers per million dollars of value added for each industry.[10]

As shown in Exhibit 14, the average metal casting facility releases roughly twice as many pounds of TRI chemicals per dollar value added than the average manufacturing facility; the comparable value for transfers is roughly four times the manufacturing sector average. Transfers, rather than on-site discharges or releases, account for the majority of TRI wastes for both foundries and die-casting facilities. The bulk of these transfers are metallic wastes, though the specific composition can vary widely across facilities.[11] The metal casting industry has a higher transfer intensity than any of the other selected industries but Plastics. As noted above, the metal casting sector has worked extremely hard to ensure that most of these offsite transfers are recycled. However, process improvements to reduce the wastes requiring recycling would likely have substantial economic and environmental benefits for the sector.

Emissions Profiles of Foundry vs. Die-Casting Segments

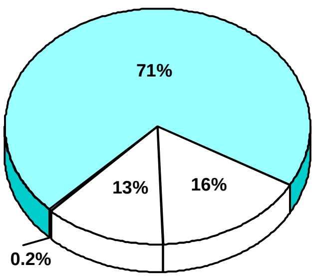
Looking within the metal casting industry, it is most useful in terms of TRI information to divide the sector into two groups: Ferrous and Nonferrous Foundries (SIC codes 332, 3365, 3366, and 3369) and Die-Casting Facilities

[10] See Footnote 9 for the definition of value added.

[11] According to U.S. EPA's *Metal Casting Industry Sector Notebook*, the most frequently reported chemical (copper) is reported by only 45 percent of metal casting facilities, and more than half of the chemicals accounting for TRI releases and transfers are reported by fewer than ten facilities.

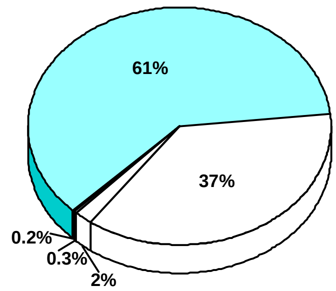
Exhibit 15
1995 TRI Releases and Transfers for Foundries
(Reported by Type of Release/Transfer in % of Pounds/Year)

Releases = 33% of Total



Percentage Shares	
Fugitive Air =	16%
Point Air =	13%
Water Discharges =	.2%
Underground Injection =	0%
Land Disposal =	71%

Transfers = 67% of Total



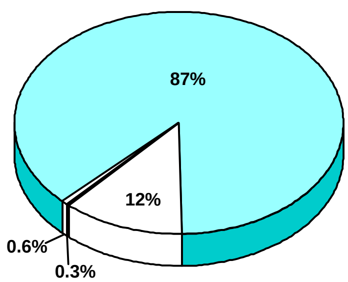
Percentage Shares	
Disposal Transfers =	37%
Treatment Transfers =	2%
Energy Recovery Transfers =	.3%
POTW Transfers =	.2%
Recycling Transfers =	61%

(Totals may not add due to rounding)

Source: U.S. EPA. EPA Office of Compliance Sector Notebook Project: Profile of the Metal Casting Industry. February 1998.

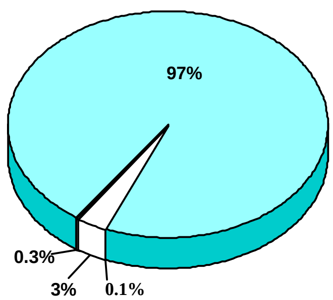
Exhibit 16
1995 TRI Releases and Transfers for Die Casters
(Reported by Type of Release/Transfer in % of Pounds/Year)

Releases = 4% of Total



Percentage Shares	
Fugitive Air =	12%
Water Discharges =	.3%
Land Disposal =	.6%
Underground Injection =	0%
Point Air =	87%

Transfers = 96% of Total



Percentage Shares	
Disposal Transfers =	3%
Treatment Transfers =	.3%
Energy Recovery Transfers =	0%
POTW Transfers =	.1%
Recycling Transfers =	97%

(Totals may not add due to rounding)

Source: U.S. EPA. EPA Office of Compliance Sector Notebook Project: Profile of the Metal Casting Industry. February 1998.

(SIC codes 3363 and 3364). As in waste characterization overall, the differences between foundry and die casting processes also result in unique TRI profiles for each of the two groups (see Exhibits 15 and 16).

Foundries. In 1995, ferrous and nonferrous foundries made up 85 percent (554 facilities) of the metal casting facilities reporting to TRI and accounted for approximately 89 percent of the total releases and transfers of the industry. Almost 57 percent, or 42 million pounds, of total TRI wastes are metallic wastes transferred off-site for recycling of the metal content. Thirty-three percent of total TRI wastes reported by the foundry sector are released to the environment (as opposed to transferred off-site). The majority of these TRI releases (over 71 percent) are released to land disposal. The metallic wastes of manganese, zinc, chromium, and lead account for most of the land disposal.

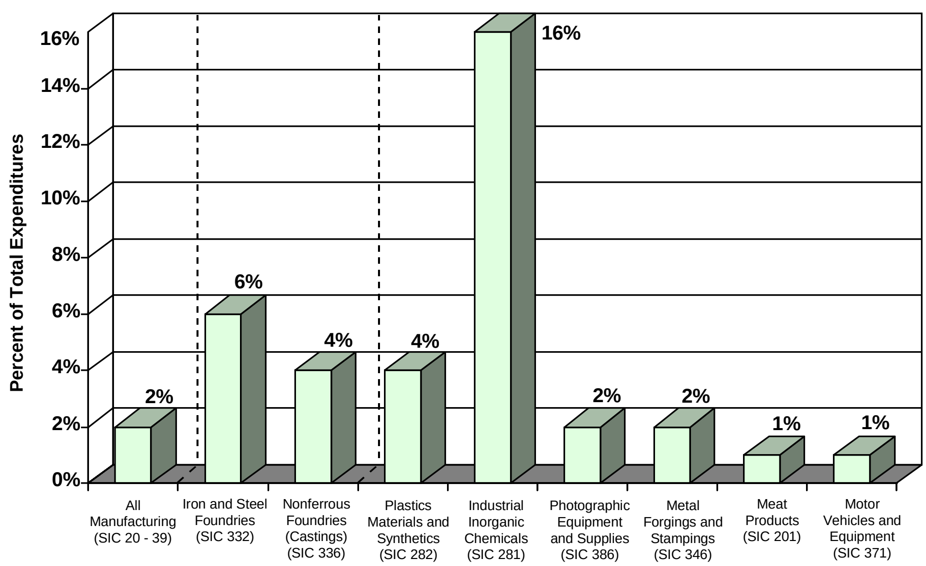
Die-Casters. Die-casters made up about 15 percent (100 facilities) of metal casting facilities reporting to TRI and were responsible for the remaining 11 percent of total transfers and releases. In this sector, off-site transfers for recycling account for approximately 96 percent, or 13 million pounds, of total TRI wastes. In contrast to foundry waste streams, only four percent of total TRI wastes reported by the die-casting sector are releases; and 87 percent of these releases are released from point sources into the air. Metallic particles of aluminum, zinc, and copper are the dominant pollutants in these die-casting emissions.

Energy Usage

The metal casting industry is an energy-intensive sector in that energy costs represent a large portion of a foundry or die caster's overall expenditures. With energy cost to total expenditure ratios of six and four percent, respectively, the ferrous foundry and nonferrous foundry sectors exceed the average for the manufacturing sector by a factor of two to three. A comparison across industrial sectors can be found in Exhibit 17.

While some sand mold curing processes require large amounts of energy in the form

Exhibit 17
1995 Ratio of Purchased Fuels and Electrical Energy to Total Expenditures by Industry Group
(Metal Casting and Other Selected Industries)



Source: Bureau of the Census. 1995 Annual Survey of Manufacturers: Statistics for Industry Groups and Industries (Washington, D.C.: Bureau of the Census, 1997). Tables 2, 3 and 4.

of heat, the majority of energy in the metal casting setting is consumed by the furnaces used to melt the metal. The U.S. EPA's *Metal Casting Industry Sector Notebook* reports that many foundry furnaces are less than 35 percent energy efficient (meaning that the other 65 percent of energy generated is lost in the form of useless waste heat). Especially in the older sectors of the industry, substantial opportunities likely exist for improvement in this area.

Pressures and Opportunities for Environmental Improvements

Two major factors drive environmental improvement in the metal casting industry: cost savings from waste reduction, and environmental regulations.

Cost Savings from Waste Reduction

Reducing the volume of wastes produced and increasing energy and other kinds of efficiency are important environmental and economic opportunities for metal casting facilities. Competitive pressures to reduce costs often have environmental benefits when part scrappage and waste is reduced or process efficiencies are improved. For instance, the need to tightly control costs has convinced a number of foundries to invest in a waste foundry sand recycling system that can recover up to 95 percent of waste sand. These systems can pay for themselves within a year and allow companies to develop a competitive edge in the market. Also, recent developments have improved the quality of die-cast recycled magnesium so that Ford, GM, Chrysler, and other automobile manufacturers have begun to use this type of recycled alloy in their automobiles.

In addition to recycling, careful evaluation of existing energy consumption patterns may also reveal economic opportunities for improved energy efficiency, even in the current era of low-priced energy. The metal casting sector already has made a great deal of progress in implementing more efficient equipment and processes, and industry groups are committed to further development of innovations in this area. Some of these opportunities are described in Attachment B.

Environmental Regulations Affecting the Metal Casting Industry

Regulatory drivers, however, continue to be the main factor in industry efforts to improve their environmental performance. The metal casting industry is governed by a host of environmental regulations that govern emissions to all media and environmental reporting (e.g., TRI). Important regulatory drivers include requirements on accumulation, storage, permitting, transport, and record keeping for wastes governed by the Resource Conservation and Recovery Act; emissions controls on discharges to POTWs under the Clean Water Act; and permitting requirements for air emissions under the Clean Air Act. The industry is also concerned about two pending air emissions standards. One involves iron and steel foundries directly; the other focuses on secondary aluminum smelters but currently includes metal casters as well. A more detailed description of the applicable regulations can be found in Attachment C.

Industry Reinvention Activities

A number of industry- and government-sponsored initiatives are underway to improve the environmental performance of the metal casting industry and to help small casters address the complex environmental regulations they face. Should the Sustainable Industry program move forward with the metal casting industry, these initiatives can leverage the impact of efforts to evaluate and streamline environmental performance. More detailed information on existing initiatives is included in Attachment D.

VII. CONCLUSIONS

The Sustainable Industry (SI) program seeks to capitalize on and enhance opportunities for "cleaner, cheaper, smarter" change. By developing a sound understanding of industry drivers and barriers through a process called "backward mapping," EPA seeks to offer industry members opportunities to go beyond compliance without compromising economic health.

The most significant cost to industry during a Sustainable Industry project effort is employee time. For a Sustainable Industry project to be successful, industry members must invest firsthand in educating EPA and participating community representatives on processes and issues. The benefits to metal casters can include enhanced efficiency, cleaner operations, reduced reporting costs, and improved worker and community relations.

Sustainable Industry pilot projects and target issues are defined by the industry and other affected parties. Sustainable Industry projects can enhance existing research and development efforts by working on parallel issues with an environmental angle. Lessons learned and actions undertaken in these industry/community/government collaborations can have both immediate effects (e.g., improved working relationships) and long term benefits (e.g., policy changes) for both metal casters and the EPA.

Industry trends and environmental concerns identified in this overview create both opportunities and challenges from the perspective of an EPA-industry partnership. The following industry characteristics make the metal casting sector attractive for participation in the Sustainable Industry program process:

- **Compliance Challenges for Small Businesses.** The majority of facilities are quite small, including between 30 and 40 percent that have fewer than 20 employees. Since environmental compliance requires a large upfront investment to understand and respond to the many detailed regulations, small firms are generally more challenged by this complexity. Devoting resources to environmental management is often difficult for small casters since these operations are typically less profitable than larger facilities.

- **Relatively High Spending on Pollution Controls**. While spending on pollution abatement and control as a percent of total costs appear low in an absolute sense (0.7 to 2.7 percent), they are fairly high in a relative sense. Foundries spent nearly three times as much on environmental controls as the average for the manufacturing sector overall. The level for nonferrous foundries was slightly below the manufacturing sector average.

- **Increased Emphasis on Quality.** The industry has placed an emphasis on quality management due to increased international competition and the demands of those purchasing castings. For example, the big three U.S. automobile manufacturers have required their Tier 1, 2, and 3 suppliers to become registered to quality management standards. The trend towards total quality management provides opportunities for improved environmental performance as well, since many of the skills that make high quality production possible (e.g., statistical process controls) apply to environmental management.

- **Capital Replacement as Portions of Industry Shift to Aluminum**. Another major competitive force in the industry, the broadscale shift from steel castings to aluminum, has led to capital replacement and the potential for improved environmental controls and energy efficiency in the newer equipment. As the industry shifts through changes in products, consolidation, outsourcing, and import substitution, many older facilities are likely to become uneconomic. Managing the transition of these firms out of the market in an environmentally responsible manner will be a significant challenge.

- **Foundry Furnaces Remain Inefficient**. Energy expenditures are substantially higher than all spending on pollution controls. In large part, this is due to old, inefficient furnaces used to melt the casting metal. Upgrades or replacements could offer large reductions in energy consumption.

- **Strong Industry Trade Association Interest.** A number of industry trade associations (described in the market overview section) have expressed interest in working with EPA as part of a Sustainable Industry Project. Trade association participation is critical to identifying and implementing promising sector-based environmental protection strategies.

Working with trade associations and other stakeholders, EPA has many opportunities to encourage new investments to include incremental improvements in energy efficiency and environmental controls, to help small business managers improve their environmental performance, and to streamline regulatory requirements to make them more understandable and less burdensome for small businesses.

ATTACHMENT A:

DETAIL ON MAJOR CASTING PROCESSES USED IN THE METAL CASTING INDUSTRY

There are many different casting processes available to manufacture cast metal parts. The best choice for a particular part depends on the detail of the design, the number of castings needed, and the cost requirements of production. Casting technologies also vary in terms of the waste products they produce, and the ease with which byproducts can be reused or recycled. A summary of the major casting processes follows.

Sand casting is the most common casting process due to sand's low cost and its ability to resist deformation under heat. Once a pattern is constructed (usually in two pieces), the pattern pieces are placed in metal boxes, or flasks, with sand shaped around the pattern halves. The sand mold is then bound with clay sand or with chemical agents. Once the mold is constructed, cores (if needed) are placed between the two mold halves, with weights placed on top to keep the two pieces together while injecting or pouring the molten metal. After casting is complete, the piece is removed from the mold, cleaned, and finished. The molds are destroyed during shakeout, with much of the sand reused in other castings.

Green sand casting is the most widely used casting process, accounting for between 70 and 90 percent of all U.S. casting. Green sand consists of 85 to 90 percent silica, olivine, or zircon sand; 4-10 percent bentonite clay; 2-10 percent carbon-based materials that burn off when the molten metal is added; and 2-5 percent water. The water and clay react to bind the sand grains and maintain mold shape. Green sand casting is used for both nonferrous and ferrous casting and is suitable for casting pieces ranging in size from very small to over a ton. Green sand is not a suitable core material, thus most green sand casting processes utilize chemically-bound cores.

In **chemically-bound sand casting**, chemical agents, rather than bentonite clay, are used to bind the sand. Widely used as cores in green sand processes, and to a lesser extent as molds, chemically-bound pieces are created using a variety of thermal, catalytic, and chemical processes and reactions. Chemically-bound molds are more stable, provide better surface finish, and last longer than those constructed of green sand. However, chemical binding is more expensive, requires more energy for sand reclamation, and generates additional air pollution during the chemical curing and metal pouring processes.

Permanent mold casting uses metal (usually iron) molds repeatedly to produce large quantities of the same size and shape pieces. Cores used in permanent mold casting are constructed of metal or, for more complex castings, sand or plaster. If non-metal cores are used, the process is referred to as semi-permanent molding. Since tooling the metal molds is generally more expensive than sand casting and other processes, a high number of castings is needed to justify mold production costs. Permanent molding generally produces less waste than sand casting since new molds are not needed for each casting. More rapid cooling imparts better mechanical properties to permanent-mold-cast parts vis-à-vis sand cast parts.

Plaster mold casting resembles sand casting, using plaster rather than sand for mold making, with the molds destroyed during shakeout. Plaster castings are of superior dimensional accuracy and surface detail and are suitable for casting intricate pieces. Limitations include higher costs than sand casting, longer process times, and incompatibility with ferrous metals.

Investment/lost-wax casting utilizes patterns constructed of wax, plastic, or other materials that occupy the cavity of the mold. The pattern is typically encased (invested) by placing the pattern in a metal flask and injecting a slurry, or by dipping the pattern repeatedly in the slurry mixture until achieving the desired "shell" thickness. Once the slurry hardens, the wax is melted, and the void left is filled with molten metal. After the casting has cooled, the slurry casing is shaken loose. Investment castings achieve the highest degree of precision and dimensional accuracy of all casting processes, making them ideal for intricate ferrous and nonferrous castings. However, the process is difficult to automate due to its large number of process steps, and its high costs of pattern preparation make it more expensive that other processes.

Lost-foam casting is similar to investment casting, with expendable polystyrene used as the pattern material. After the slurry hardens, the piece is placed in a flask, surrounded by loose sand as well as sand compacted around the pattern. Molten metal is then poured into the flask, vaporizing the polystyrene and replacing it with metal. This process is used for both ferrous and nonferrous precision pieces of high complexity requiring superior surface finish. It is easily automated and utilizes low-cost raw materials, making it a cost-effective alternative to investment casting.

Die-Casting is similar to permanent mold casting. Steel molds (dies) are employed, with molten metal injected under high-pressure using a hot-chamber or cold-chamber casting machine. In hot-chamber machines, the metal injection mechanism is submerged in a reservoir of molten metal. Hot-chamber machines are best for low-melting point materials, since the injection mechanism will break down under high heat. In cold-chamber machines, the injection mechanism is not submerged in molten metal, making this process suitable for casting higher melting-point alloys. Die-casting machines produce large quantities (up to several hundred pieces per hour) of castings with complex shapes and high quality finishes.

ATTACHMENT B:

OPPORTUNITIES FOR IMPROVED ENVIRONMENTAL PERFORMANCE IN THE METAL CASTING INDUSTRY

Reducing and Reclaiming Waste Sand. Although most foundry sand is reused, substantial waste quantities are still generated. Waste quantities tend to be higher when casting techniques relying on bound sand (where grains are chemically bound together) rather than loose sand are used. As foundries begin to account for waste disposal costs in evaluating the cost-effectiveness of various casting methods, methods like lost-foam casting (which uses loose sand) will become increasingly attractive. Even with bound sands, however, screening systems, magnetic separators, and dry scrubbers can be used to segregate reusable sand from other wastes (such as furnace dust and metal particles) and to separate particles of varying sizes. Binding agents can be removed using a variety of thermal processes. Non-hazardous waste sand often can be recycled for use in construction materials.

Furnace Energy Demand and Air Emissions. Foundry furnaces' energy efficiency often can be drastically improved through new oxygen burners, computerized gas-flow metering, and regenerative ceramic burner systems. Industry claims these investments are not being made due to low profitability in the industry; however, further research might identify applications where upgrades have a rapid payback. Other opportunities include replacing arc and cupola furnaces with more energy efficient, less polluting induction furnaces and reducing the amount of cast metal removed during finishing. Particulate emissions can be reduced by switching from fuel oil to natural gas in furnaces that have that flexibility. Air emissions from oil-burning furnaces can be reduced by using lower grade fuel oils, low sulfur fuel oils, and low nitrogen fuels. Proper furnace maintenance also reduces energy consumption and air pollution.

Furnace Dust. The amount of dust generated by furnaces can be reduced by maintaining optimal furnace operating parameters. Many furnace dusts can be recycled for metal reclamation.

Wastewater. Oils and phenols from lubricants used in die casting are the most common wastewater constituents generated by metal casting operations. Substituting phenol-free lubricants is the simplest way to reduce phenol emissions. While these substitutes cost more than conventional lubricants, their cost is offset by reduced environmental control costs. Alternative lubricants can also significantly reduce volatile organic compounds (VOCs) and particulate air emissions. Separating phenol-based wastes from other oil wastes through catch pans can reduce the quantity of phenol wastewater generated as well.

Wastewater and wastewater sludge can be reduced by installing cooling water recycling systems, adjusting post-casting finishing processes to reduce suspended solids generated, and dewatering sludge with filters and pH controls.

Residual Wastes. Residual wastes in the casting industry can be reduced by reusing and recycling packaging materials, segregating waste streams, implementing proper equipment maintenance, and increasing the use of drip pans and other containment measures.

ATTACHMENT C:

OVERVIEW OF ENVIRONMENTAL REGULATIONS AFFECTING THE METAL CASTING INDUSTRY

A variety of federal and state environmental regulations apply to the metal casting sector. The U.S. EPA's *Metal Casting Industry Sector Notebook* reports the following to be among the most significant regulations for the metal casting industry:

- *Resource Conservation and Recovery Act (RCRA)*—various accumulation, storage, permitting, record keeping and other related standards for facilities handling regulated hazardous wastes. A number of waste types produced by metal casting facilities, including slag, dust, sludge, and sand, may meet corrosivity criteria and other definitions of hazardous waste triggering RCRA standards. In addition, sand waste may be reclaimed in a thermal treatment unit potentially subject to RCRA requirements for hazardous waste incinerators. For foundries that have historically used land disposal as a primary disposal method, two of the most significant provisions are those of the LDR (land disposal restrictions) for particular untreated hazardous wastes and the corrective action provisions, which require remediation for certain previously released hazardous wastes.

  – *pending/proposed regulation under RCRA*: provisions addressing regulation of impermissible dilution (adding iron dust or filings to spent sand as form of stabilization); and provisions addressing regulation of thermal processing or reclamation units (TRUs) to remove contaminants from spent foundry sand.

- *Clean Air Act (CAA)*— including: Title V permits under which major source facilities must apply for permits and meet monitoring and other requirements; New Source Review (NSR) requirements under which new or expanded facilities located in non-attainment areas may be subject to lowest achievable emission rate (LAER) standards, best available control technology (BACT) standards, and/or continuous on-site air quality monitoring standards.

  – *pending/proposed regulation under CAA*: Maximum Achievable Control Technology (MACT) requirements under National Emissions Standards for Hazardous Air Pollutants (NESHAP) standards for ferrous foundries (nonferrous foundries and die casting facilities will not be subject to NESHAP standards).

- *Clean Water Act (CWA)*—National Pollutant Discharge Elimination System (NPDES) permits must be obtained by facilities who discharge wastewater into navigable waters as well as for some facilities with significant stormwater discharges. Industry-specific effluent limitations guidelines, new source pretreatment and performance standards, and pretreatment standards for existing sources are grouped according to type of metal cast (e.g., zinc, copper) under the Metal Molding and Casting Point Source Category within the CWA. In addition, facilities that discharge to a POTW may be required to meet general industry National Pretreatment Standards for some contaminants.

- *Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)*—The type of metal compounds that form the majority of waste from the metal casting sector are commonly found at sites falling under CERCLA regulation, and a number of sites containing foundry waste are currently on the National Priorities (Superfund) List. In general, metal casting facilities must meet certain reporting standards required under CERCLA as well as under the Superfund Amendments and Reauthorization Act (SARA) and Emergency Planning and Community Right-to-Know Act (EPCRA), which require regulated facilities to submit TRI data.

- The metal casting industry also is impacted by environmental regulations affecting other industries that are upstream or downstream from the casting process. For instance, foundries reliant on the sand mining industry for mold preparation could suffer due to environmental protection actions that curb sand mining activities. As mentioned before, the metal casting industry also has been significantly affected by the automobile industry's emphasis on building lighter-weight vehicles to increase gas efficiency in compliance with the corporate average fuel economy (CAFE) standards.

ATTACHMENT D

EXISTING GOVERNMENT AND INDUSTRY PROGRAMS SUPPORTING THE METAL CASTING INDUSTRY

Federal Research Support. The U.S. government is the metal casting industry's most generous collaborative research partner. The Department of Energy, the National Institute of Science and Technology, the National Air and Space Administration, and the National Science Foundation have contributed a combined total of approximately $50 million over the past several years. In addition, the industry also works with state governments.

Department of Energy's Metal Casting Competitiveness Research Act of 1990. Industry representatives argue that the cost of compliance forces small foundries to invest in control measures instead of reduction or elimination strategies. In the *Metalcasting Industry Technology Roadmap*, the authors outline their suggestions for environmental research and development issues, and explain that the small businesses that characterize the metal casting industry will not able to conduct these studies without government funding. Through the Department of Energy Metal Casting Competitiveness Research Act of 1990, the government currently provides research grants targeted at improving metal casting technology and energy efficiency. Institutions conducting research with these grants include the University of Alabama, Ohio State University, and Case Western Reserve University.

Department of Energy's Beyond 2000. In 1995, metal casting industry leaders, in partnership with the U.S. Department of Energy's (DOE) Office of Industrial Technology, published *Beyond 2000: A Vision for the American Metalcasting Industry*—a report describing a framework under which the industry will become more competitive, more productive, and more efficient by the year 2020. In 1997, the group published a "roadmap" of the process for achieving the goals outlined in Beyond 2000 and, together with DOE, sponsored a workshop to explore the process further.

Castings Emissions Reduction Program. In anticipation of new clean air regulations beginning in 2000, the Castings Emissions Reduction Program (CERP) has been established to conduct the research and development of environmentally friendly and cost-effective casting equipment. The program manager of CERP explains that the metal casting industry does not currently have the technology to comply with the strict regulations. CERP Chairman Dennis Schuetzle says, "The success of this project is made possible by the close cooperation between industry, government, and academia. Our individual organizations don't have the resources or expertise to do it alone." The program has developed a pilot foundry on which they will test their new equipment.

Other Industry Technology Transfer Consortia. Notable industry programs sponsored by the trade associations include: the American Metalcasting Consortium (AMC), a group of six prominent metalcasting organizations joined together to mobilize small and medium sized foundries around the issues of training, market growth, technology transfer, and applied research; the Cast Metals Coalition (CMC), a group of chief industry representatives that has undertaken a goals development project called *Beyond 2000: A Vision for the American Metalcasting Industry* in conjunction with the Department of Energy's Office of Industrial Technologies; and the Pennsylvania Foundry Consortia, a group of Pennsylvania foundries and industry experts who are working under a grant from the U.S. EPA on issues associated with solid waste disposal, sand reclamation, and the beneficial use of foundry residual wastes.

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